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Study on Optimization Method of Aircraft Maintenance Plan Based on Longest Path

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Abstract: From the point of view of saving costs and increasing revenue of airlines, the optimization model of Aircraft Maintenance is established based on the objective function of maximizing the airline fleet aircraft utilization, the longest path heuristic algorithm is introduced, with the description of the initialization, allocation and assessment of the algorithm on details and the optimization model based on this algorithm using specific data from the airline is solved. It demonstrates the significance and practical meaning of this method.

Key words: Maintenance plan, optimization model, the longest path heuristic algorithm

INTRODUCTION

Airline companies are faced to various optimization problems while the planning of operation (Clarke *et al*., 1997). One of these optimization problems is maintenance plan which effects directly the costs and income of an airline. Aircraft maintenance plan is to combine the limited resource with the maintenance task needed, in order to reasonably arrange the maintenance procedures, to make the most use of the maintenance equipments and aviation material and to well allocate maintenance workers. Aircraft maintenance is a very complete and systematic task. An improper maintenance plan leads a waste of resource and duplication of investment. For example, information, tools and equipment cannot be shared, as well as aviation materials and maybe there are too many maintenance bases.

While preparing the aircraft maintenance plan, maintenance constraints have to be taken into account. The particular maintenance constraint considered in this work is the limited flight hours between two maintenance checks. We can see short term maintenance checks, mid-term maintenance check and long term maintenance checks. As the maintenance checks are highly expensive activities, a good plan allows the maximization of the aircraft utilization without exceeding legal flight hour limit.

Several works on classical fleet assignment problem which is often modeled as a mixed integer linear multi commodity flow, over a daily horizon can be found. Subramanian *et al*. (1994) add some constraints to a large scale mixed integer linear model to take into account maintenance checks. Sarac *et al*. (2006) propose a branch-and-price algorithm for a daily aircraft rotation problem to minimize the assignment costs. Clarke *et al*. (1996) extend the model by maintenance and crew constraints and solve it. Sriram and Haghani (2003) model the weekly aircraft rotation problem with maintenance costs and maintenance base capacity constraints. Sun *et al*. (2007) propose a Particle Swarm Optimization Algorithm to solve the maintenance plan model. Xiao and Zhu (2007) proposes flight-loop's dynamic construction method in aircraft scheduling. Li *et al*. (2008) builds a discrete particle optimization algorithm which uses a particle value selecting mode and a particle velocity changing way for the model.

MODEL

Based on the maintenance manuals, an optimization model is established when taking into account all the affect factors (human factor (Zhang *et al*., 2008), type of check, type of aircraft, climate, maintenance base, etc). In this study, we should make some hypothesis to simplify this problem:

- Without knowing about the flight routing plan
- A reasonable flexible time limit before check
- Only one type of aircraft
- Without considering special holidays and climate affect
- Single maintenance base

Parameter and variable: The ensemble of the aircrafts is expressed by Ac. The ensemble of flights of the kth aircraft in Ac from the beginning of the planned period to A check is $j \in$ into(Am_k), The ensemble of flights of the kth aircraft in Ac from the beginning of the planned period to C check is $j \in$ into(Cm_k). T_j presents the duration of flight j, T^Y_k presents the used time of aircraft k at the end of the planned period. The main variables are y_{cik} and y_{Aik}. If there is C check of aircraft k on the ith day y_{cik} is 0, If there is no C check of aircraft k on the ith day, y_{cik} is 1; If there

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is A check of aircraft k on the ith day, y_{Aik} is 0, If there is no A check of aircraft k on the ith day, y_{Aik} is 1. $T^{Cm}{}_k$ is the potential flight time of aircraft k from the beginning of the planned period to a C check, $T^{Am}{}_k$ is the potential flight time of aircraft k from the beginning of the planned period to an A check. Cperiod is the interval between two C check, Aperiod is the interval between two A check. Pct is set to be the flexible time limit between two maintenance check. Cwindow and Awindow are the duration (days) of C check and A check. N is the capacity of maintenance base.

Model establishment:

$$\max \left(\sum_{k \in A_c} T_k^{Am} + \sum_{k \in A_c} T_k^{Cm} \right)$$

s.t.:

$$T_k^r + \sum_{j \in into(Am_k)} T_j = T_k^{Am}; \ \forall k \in A_c \quad (1)$$

$$T_k^r + \sum_{j \in into(Cm_k)} T_j = T_k^{Cm}; \ \forall k \in A_c \quad (2)$$

$$T^Y{}_k \leq Cperiod \quad (3)$$

$$Cperiod.(1\text{-}Pct) \leq T^{Cm}{}_k \leq Cperiod \quad (4)$$

$$Aperiod.(1\text{-}Pct) \leq T^{Am}{}_k\text{-}T^Y{}_k \leq Aperiod \quad (5)$$

$$\sum_{k \in A_c} y_{C,i,k} + \sum_{k \in A_c} y_{A,i,k} \leq N; \forall i \quad (6)$$

$$y_{C,i,k} \in \{0, 1\}; \quad \forall i, \forall k \in A_C \quad (7)$$

$$y_{A,i,k} \in \{0, 1\}; \quad \forall i, \forall k \in A_C \quad (8)$$

$$\sum_i y_{C,i,k} \leq Cwindow \quad (9)$$

$$\sum_i y_{A,i,k} \leq Awindow \quad (10)$$

Objective function and restraints: The first part and second part of the objective function are to maximize the flight time before A check and C check that leads to a maximal use ratio of the aircrafts. Conditions 1 and 2 are the restraints of flight time before A check and C check. Conditions 3-5 is to restriction of the intervals between two A checks and two C checks. In order to have a cost as small as possible and also make sure the safety of flight, we control the aircraft cannot be checked until the used flight time arrive the flexible time limit. Condition 6 makes sure the number of the under checked aircrafts everyday is no more than the capacity of the maintenance base. Conditions 7-8 are the restraint of the model as a whole. Conditions 9-10 are the restrictions of the duration of A check and C check.

ALGORITHM

The aircraft maintenance optimized model is a very complex problem, it has many variables and restraints. It is very difficult to find a method to decide the optimal solution. Compared the method to find the optimal solution, we prefer to use an adapted algorithm to find an appropriate solution that is the longest-road heuristic algorithm. We should start from the random initialization of the maintenance activities and take the method of iteration and improvement, until we can approach the optimal solution which is the appropriate one. This algorithm can make us use limited space and limited time to get the more effective solution. This is more meaningful for the aviation industry.

Initialization:

- Compute the used flight time of each aircraft of the ensemble
- Compute and decide the specific date of A check and C check of each aircraft using the restraints of the edge of A check and C check

Allocation:

- Based on the principle of the number of under checked aircrafts is smaller than the capacity of the maintenance base, we make the reversed sequence of all the aircrafts
- If the number of under checked aircrafts is bigger than the capacity of the maintenance base, we choose randomly an under A check aircraft and move towards $d_{A,k}$ days, if all the under A check aircraft are moved but the number of under checked aircrafts is still bigger than the capacity of the maintenance base, we move successively the under C check aircrafts of $d_{C,k}$ days in the same way
- Make sure the restraints is adapted to the flexible time limit. Get the statistic results

Assessment: For every obtained condition, use the assessment function:

$$\sum_{k\in A_c} d_{A,k}^2 + \sum_{i=1}^{n} {}_i^2 d_{C,k}^2$$

to compute the variance of the ideal solution. The smaller the variance is, the better the solution is.

EXAMPLE ANALYSIS

To check the model and the algorithm above, we choose 9 aircrafts in April of an airline to be an example. we consider planned period of one month (30 days), the daily use ratio of an aircraft is 10 FH day^{-1}, the interval between two C check and two A check are 3500 and 200 FH the capacity of the maintenance base is 3.

Compute the used flight time of aircraft k is UTime, decide the interval [200 n, 200(n+1)] (n = 0, 1, 2,... 15) of UTime, compute the results of D_A= ((200 (n+1)-UTime)/10 and D_A = ((200(n+1)-UTime)/10)+20 (there are 2 A check at most) which are the numbers of days arriving to A check; compute the result of D_C = (3200-UTime)/10 which is the number of days arriving to C check. For example: the used flight time of aircraft is 2710 FH, the numbers of days to A check and C check are D_A = (2800-2710)/10 = 9, D_A = 9+20 = 29, D_C = (3200-2710)/10 = 49. If one day has A check and C check at the same time, we only consider the C check (Table 1).

We find the 9 and 10th day from the planned period cannot meet the principle of the number of under checked aircrafts is smaller than the capacity of the maintenance base, we move the A check in the backwards order (Table 2), (presents kth aircraft, i presents the ith day when we need to move the aircraft backward).

Table 1: The used flight time and the number of days to the A check and C check

	Utime (FH)	No. of days to next A check	No. of days to next C check
2710	9	29	49
3100	10	30	10
2600	0	20	60
3130	7	27	7
2805	20	40	210
1100	10	30	9
3110	9	29	209
1110	9	29	260
500	10	30	260

Table 2: Adjustment of the aircrafts and assessment

I = 10	i = 9	$\sum_{k\in A_c} d_{A,k}^2 + \sum_{k\in A_c} d_{C,k}^2$
⑥	① ⑥	5
	① ⑧	3
	⑥ ⑧	5
⑨	① ⑧	3
	① ⑨	5
	① ⑨	5

From the results we can conclude that if we move the 6th aircraft in 10th day towards 1 day and move the 8th and 1st aircrafts in 9th day towards 1 day, we can get the appropriate solution or else if we move the 9th aircraft in 10th day towards 1 day and move the 8th and 1st aircrafts in 9th day towards 1 day, we can get the same appropriate result.

CONCLUSION

From the point of view of saving costs and increasing revenue of airlines, this article establish the optimization model of Aircraft Maintenance based on the objective function of maximizing the airline fleet aircraft utilization. Then it introduces the longest path heuristic algorithm, giving a good description of the initialization, allocation and assessment of the algorithm on details and the optimization model based on this algorithm using specific data from the airline is solved which demonstrates the significance meaning of this method. By this way, a practical and effective method of aircrafts maintenance plan for airlines.

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REFERENCES

Clarke, L., E. Johnson, G. Nemhauser and Z. Zhu, 1997. The aircraft rotation problem. Ann. Oper. Res., 69: 33-46.

Clarke, L.W., C.A. Hane, E.L. Johnson and G.L. Nemhauser, 1996. Maintenance and crew considerations in fleet assignment. Trans. Sci., 30: 249-260.

Li, Y.H., N. Tan and G.H. Hao, 2008. Optimization model and algorithm of aircraft maintenance plan. Control Eng. China, 15: 99-102.

Sarac, A., R. Batta and C.M. Rump, 2006. A branch-and-price approach for operational aircraft maintenance routing. Eur. J. Oper. Res., 175: 1805-1869.

Sriram, C. and A. Haghani, 2003. An optimization model for aircraft maintenance scheduling and re-assignment. Trans. Res., Part A: Policy Pract., 37: 29-48.

Subramanian, R., R.P. Scheff, J.D. Quilinian, D.S. Wiper and R.E. Marsten, 1994. Coldstart: Fleet assignment at delta air lines. Interfaces, 24: 104-120.

Sun, C.L., K. Cui and Y.H. Li, 2007. Optimum study on aircraft maintenance plan based on particle swarm optimization algorithm. J. Civil Aviation China, 25: 29-31.

Xiao, X.D. and J.F. Zhu, 2007. Flight-loop's dynamic construction method in aircraft scheduling. Syst. Eng., 25: 19-25.

Zhang, K., D.S. Gao and W.Q. Dong, 2008. The human factors in aircraft maintenance planning and engineering and maintenance. China Civil Aviation, 132: 56-61.